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REPORT OF SURVEY CONDUCTED AT

NORTHROP GRUMMAN
CORPORATION
EL SEGUNDO, CA

FEBRUARY 1998

Best Manufacturing Practices

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
College Park, Maryland
www.bmpcoe.org

Foreword

This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at the Northrop Grumman Corporation, El Segundo, California conducted during the week of February 23, 1998. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared.* BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

Northrop Grumman maintains core values of customer satisfaction, employee opportunity, environmental compliance, and community outreach. The overall philosophy is to draw upon skills throughout the company so that the very best technologies, processes, and intellectual capital are brought to each program. This outlook enables the company to achieve creative vision, environmental management, and financial advantage necessary to compete in the 21st Century. Among the best examples were Northrop Grumman's accomplishments in elimination of ozone depleting chemicals; work in process cans; chemical tracking system; and Title V operating permits program.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Northrop Grumman expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Ernie Renner
Director, Best Manufacturing Practices

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Report Summary

Background

The Northrop Grumman Corporation can trace its history back through the pioneering founders of aviation — Jack Northrop, the Loughead [*sic*] brothers, Donald Douglas, and Leroy Grumman, to name a few. Over the years, the company transformed itself from an airplane manufacturer into a premier electronics and systems integration corporation. Today, Northrop Grumman is a leading designer, systems integrator, and manufacturer of military surveillance and combat aircraft; defense electronics and systems; airspace management systems; information systems; marine systems; precision weapons; space systems; and commercial and military aerostructures.

With its corporate headquarters in Los Angeles, California, Northrop Grumman is organized into five divisions, employs 52,000 personnel, and achieved $9.2 billion in sales for 1997. The BMP survey focused on Northrop Grumman's Military Aircraft Systems Division which employs 14,000 personnel, encompasses 320 acres, and achieved $2.6 billion in sales for 1997. This Division, based in El Segundo, California, is a world-class leader in the manufacture of military aircraft and unmanned airborne vehicles; systems integration and engineering research and development; aerostructure modifications; and upgrades to military air vehicles. Although Northrop Grumman was recently surveyed by BMP in October 1997, this survey focused on the environmental practices of the Military Aircraft Systems Division. Among the best practices documented were Northrop Grumman's elimination of ozone depleting chemicals; work in process cans; chemical tracking system; and Title V operating permits program.

As the principal subcontractor to Boeing (formerly McDonnell Douglas), Northrop Grumman produces the center and aft fuselage sections; the twin vertical stabilizers; and all associated subsystems for the U.S. Navy F/A-18 Hornet strike fighter. The F/A-18 production line is housed in the world's longest, all-wooden building. Constructed entirely of redwood, the 0.5-mile long F/A-18 assembly building still reflects its World War II design of a long, single production-specific line. Other key contracts include the Joint Strike Fighter, the J-STARS Aircraft Mod, and the B-2 Spirit Bomber programs.

The southern California region is one of the most regulated and environmentally restricted parts of the United States for manufacturers. Northrop Grumman learned early on that the regulatory agencies did not have a good understanding of the aerospace industry, and thus the company has taken an active role in the environmental regulatory and rule making process for many years. Only by companies working with regulators can rules be adopted that will achieve their intended goals and work for both groups. Northrop Grumman also maintains core values of customer satisfaction, employee opportunity, environmental compliance, and community outreach. The overall philosophy is to draw upon skills throughout the company so that the very best technologies, processes, and intellectual capital are brought to each program. This outlook enables the company to achieve creative vision, environmental management, and financial advantage necessary to compete in the 21st Century. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at Northrop Grumman:

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In July 1992, South Coast Air Quality Management District Rule 1171 mandated that spray guns must be cleaned in an enclosure to reduce emissions from volatile organic compound-containing materials. This rule also regulates emissions from the storage and disposal of the solvents used during the cleaning operation. As a result, Northrop Grumman switched to a Cascade Closed Loop Cleaning system for its paint spray guns.

Information

The following information items were documented at Northrop Grumman:

Point of Contact

For further information on items in this report, please contact:

Mr. Paul Lehman, III
Northrop Grumman Corporation
Military Aircraft Systems Division
One Hornet Way, PA11/W9
El Segundo, California 90245
(310) 331-7781
FAX: (310) 332-3486
E-mail: lehmapa@mail.northgrum.com

Section 2

Best Practices

Production

Cascade Closed Loop Cleaning System

Previously, the Northrop Grumman Corporation, Military Aircraft Systems Division (MASD) cleaned its paint spray guns by dispersing solvent through the gun, or by disassembling the gun and cleaning the component parts in solvent. In July 1992, South Coast Air Quality Management District (SCAQMD) Rule 1171 mandated that spray guns must be cleaned in an enclosure to reduce emissions from volatile organic compound-containing materials. This rule also regulates emissions from the storage and disposal of the solvents used during the cleaning operation.

As a result, Northrop Grumman switched to a Cascade Closed Loop Cleaning system for its paint spray guns. The spray gun is placed in the cleaning unit with the fluid passage mated to the unit's solvent system. This automatic cleaning unit pumps solvent through the spray gun as well as over the external areas of the gun. The siphon cup can be cleaned simultaneously with the gun, but must first be removed from the spray gun before cleaning. A timed cycle on the unit can be repeatedly run as many times as necessary to clean the spray gun. The solvent is also reused until it is no longer effective for cleaning.

Since implementing the Cascade Closed Loop Cleaning system, Northrop Grumman reduced the amount of volatile organic compounds being released into the atmosphere. This system also enables the company to comply with SCAQMD Rule 1171.

Elimination of Ozone Depleting Chemicals

As a result of SCAQMD regulations, Department of Defense contract requirements, the Federal Clean Air Act, the Montreal Protocol, and the 1995 ban on the production and distribution of ozone depleting chemicals (ODCs), Northrop Grumman implemented Corporate Directive 128:TJM:93-064 in 1991. This Directive required the virtual elimination of the use of all ODC materials and emissions in the company's 15 facilities over a five-year period.

Using 1991 as a baseline, 686 various production operations and 110 different materials containing Class 1 ODCs accounted for more than one million emission pounds at Northrop Grumman, MASD. In general, these operations can be grouped into five major areas: degreasing (77.52%), painting (14.83%), gun cleaning (3.00%), wipe solvents (1.68%), and miscellaneous uses (2.97%). Over a five-year period, Northrop Grumman, MASD reduced its ODC emissions by a whopping 99.9%. The vast majority of these reductions (nearly 80%) can be attributed to a scheduled program, which decommissioned 1,1,1-trichloroethane vapor degreaser tanks and replaced them with water aqueous degreaser tank lines (Figure 2-1). The remaining reductions were accomplished through material and chemical substitutions;

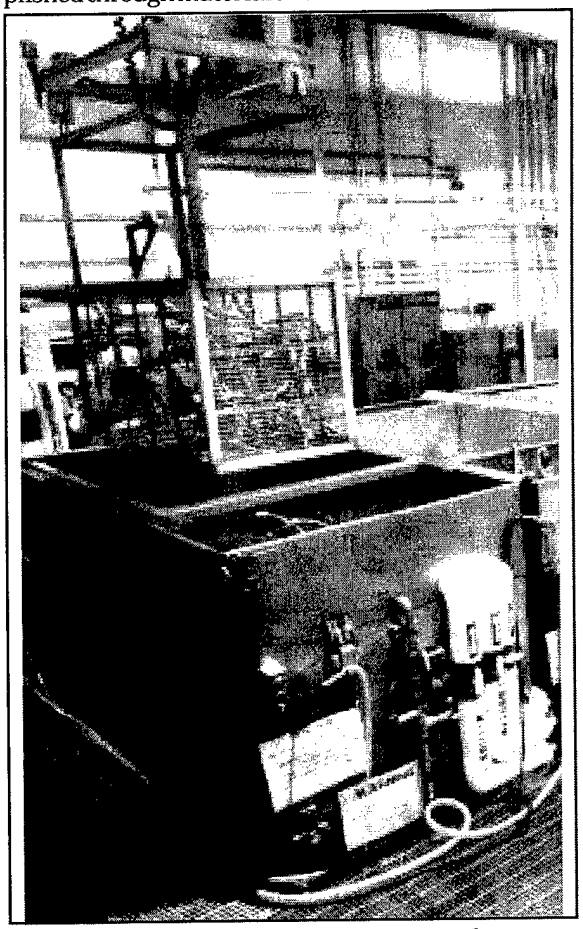


Figure 2-1. Aqueous Degreaser Tank

production process and manufacturing changes; and employee education programs. Today, the Northrop Grumman, El Segundo facility has zero ODC emissions and uses no ODC materials in its production processes.

By eliminating ODCs from the production processes, Northrop Grumman became fully compliant with the environmental regulations governing ODC materials, eliminated ODC emissions, and reduced production costs. In addition, the company improved the health and safety of its employees and customers, and contributed to a cleaner and healthier environment.

Emission Factor Refinement

In 1986, the State of California passed Proposition 65 which required industrial manufacturers that generate toxic air emissions to notify the public in the immediate area that there may be a risk of exposure to known carcinogenic substances. Northrop Grumman's primary toxic emission is hexavalent chromium (HexCr), generated from the production spray booths and touch-up spray operations on its manufacturing and assembly lines. Accurate emission factors are critical to determine the exact amount of total emissions released into the environment and the expected level of exposure. Instead of relying on generally accepted emission factors from various published sources, Northrop Grumman developed a source testing process which refined the emission factors. The process significantly reduced the estimated emission rate and toxic exposure risk, thereby eliminating the need to notify the general public of a toxic substance risk.

Emission factors are mathematical equations used to estimate the total amount of airborne substance emissions from a given substance and process. In the case of spray booth operations, the equation for estimated total emissions would be:

> EMISSIONS = (POUNDS PROCESSED) * (1-TE) * (1-DO) * (1-CE), where TE is the transfer efficiency; DO is the dropout percentage; and CE is the control efficiency.

Typical emission factor sources are: supplier equipment specifications; Air Pollutant 40 and 42 Published Data; state and local published and/or customary and accepted values; or the California Air Resources Board Published Toxics Data. In the case of agency-approved spray booth factors using typical emission factor sources, the calculated values are:

- TE for the high volume, low pressure (HVLP) spray guns is 0.65;
- DO of material not airborne is 0.22;
- CE using dry filters is 0.97;
- CE for water wash spray booths is 0.90; and
- CE for High Efficiency Particulate Arrester (HEPA) filters is 0.9997.

For the West Complex spray booths (Buildings 915 and 923) and the touch-up spray operations (Building 902), these calculations translate to a combined 0.351 pounds of HexCr emissions. However, Northrop Grumman's source testing process (which uses actual mass balance) calculates the CEs more accurately for inclusion in the emission factor equation, and reduced the combined amount of HexCr emissions by 92%. These values are then used to determine the Maximum Individual Cancer Risk (MICR) from the emissions exposure. By using source testing values, the MICR is reduced from 189 per million with typical emission factors to nine per million (an MICR of ten per million is considered significant).

Northrop Grumman's method of calculating emission factors greatly reduces the estimated toxic exposure risk; ensures compliance with state and local air quality regulations; controls costs; and increases operational flexibility. As a result, the company enhances its image and relationship with local neighbors.

Emissions Reductions

Northrop Grumman, MASD uses chromium-bearing primers and paint for the coatings on its F/A-18 airframes. Through Proposition 65 (Safe Drinking Water and Toxic Control Enforcement Act), California law mandates that companies must notify the public via local newspaper announcements regarding all areas (hot spots) containing a chemical known to the State of California to cause cancer, birth defects, or other reproductive harm. This type of public announcement can be very damaging to a company's image with the local community. In 1995, Northrop Grumman set out to eliminate the requirements for posting these public announcements by initiating an aggressive goal to reduce off-site potential health risks due to chromium VI emissions. This goal aligns with the Corporate goal (using a 1995 baseline) for a 50% reduction in toxic air emissions by the year 2001, and has eliminated the requirements for public notification of hot spots under Proposition 65. Between 1990 and 1995, toxic emissions were reduced by more than 80%.

One of Northrop Grumman's innovative methods for reducing air emissions was its development of

Portable Air Pollution Control Equipment (PAPCE), using $6,500 of commercial-off-the-shelf equipment. The company patented and built ten PAPCE units for spray coating touch-up operations (Figure 2-2). PAPCE, a small portable vacuum with HEPA filters, easily rolls into position to capture any overspray associated with touch-up spray coating operations. Greatly valued by the employees, this compact unit operates with minimal impact on the work area and is equipped with a manometer which alerts operators to change the HEPA filters when the vacuum reaches two inches of mercury. In addition, each PAPCE displays a California air emissions permit. Northrop Grumman had to establish and obtain regulatory approval for the capture efficiency of these units. HEPA filters are designed to operate at 99.97% efficiency. PAPCE has an overall removal efficiency of 88%. Other potential uses for PAPCE include welding, grinding, and drilling operations. PAPCE is also effective for volatile organic compounds (VOCs). The unit has been upgraded to explosion-proof and carbon filters were installed to capture VOCs.

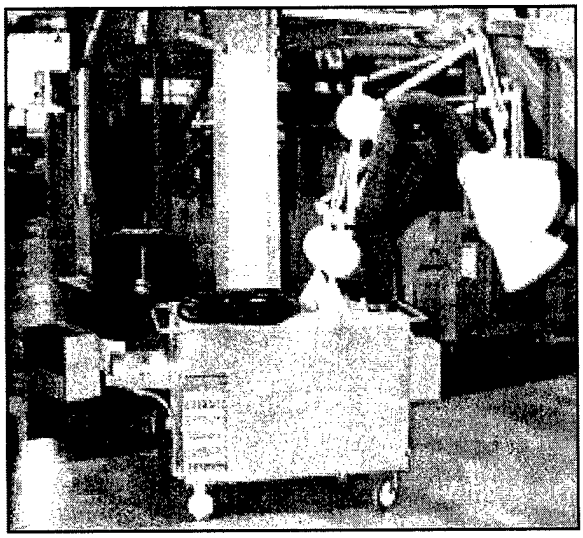


Figure 2-2. Portable Air Pollution Control Equipment

Another innovative approach undertaken by Northrop Grumman for eliminating air emissions was to outfit the roof of Building 923 (large-scale painting facility) with a very large HEPA filter array. This HEPA filtered exhaust system handles all of the exhaust air for the three large paint booths housed in the building. In addition, each booth is equipped with manometers which alert operators to stop spraying if two inches of mercury is exceeded. Benefits of the HEPA filter system include a cheaper installation cost compared to scrubbers; minimal production disruptions; simplified operational and maintenance requirements; and elimination of all groundwater and soil contamination concerns.

By implementing air emission control systems for its paint and coating applications, Northrop Grumman has significantly reduced its air emissions. The company's innovative uses for HEPA filters decreased potential health risks due to chromium VI emissions, and reduced the hot spot areas of public notification under Proposition 65 by more than ten square miles. In addition, the Northrop Grumman, El Segundo operations had no off-site risk impact for three consecutive quarters in 1997.

Environmental Control Room

Northrop Grumman's Environmental Control Room is the center of all activities related to regulatory tracking and planning for environmental initiatives. The company's commitment to be proactive in environmental issues starts with top-level environmental goals that are linked to the Division's Annual Operating Plan (AOP). Departmental supplemental goals define the pollution prevention objectives for each department, and are written into each manager's performance objectives. As a result, the responsibility for implementing these goals flows down the management chain.

Regulatory tracking and planning for new regulations are important functions which help Northrop Grumman prepare for new requirements and be proactive in shaping new rules. Many times regulatory agencies may not have the in-depth knowledge of production process requirements to allow them to analyze the effect that new rules will have on companies. In many cases, Northrop Grumman worked in conjunction with other industries in the area to influence new regulations in a manner that caused the least impact on production operations. Rather than wait for the new rules to be implemented and then discover that production would be impacted, Northrop Grumman's proactive approach accomplishes the regulatory agency's goals and ensures that its own operations will not be adversely impacted.

Each division goal related to the AOP's environmental issues is tracked for progress through tactic plans with milestone charts and periodic reviews for progress toward meeting those goals. Activities related to accomplishing the goal are identified along with the person responsible, and a priority is then assigned to each task. Risk levels are also assigned to each activity as well as a risk status.

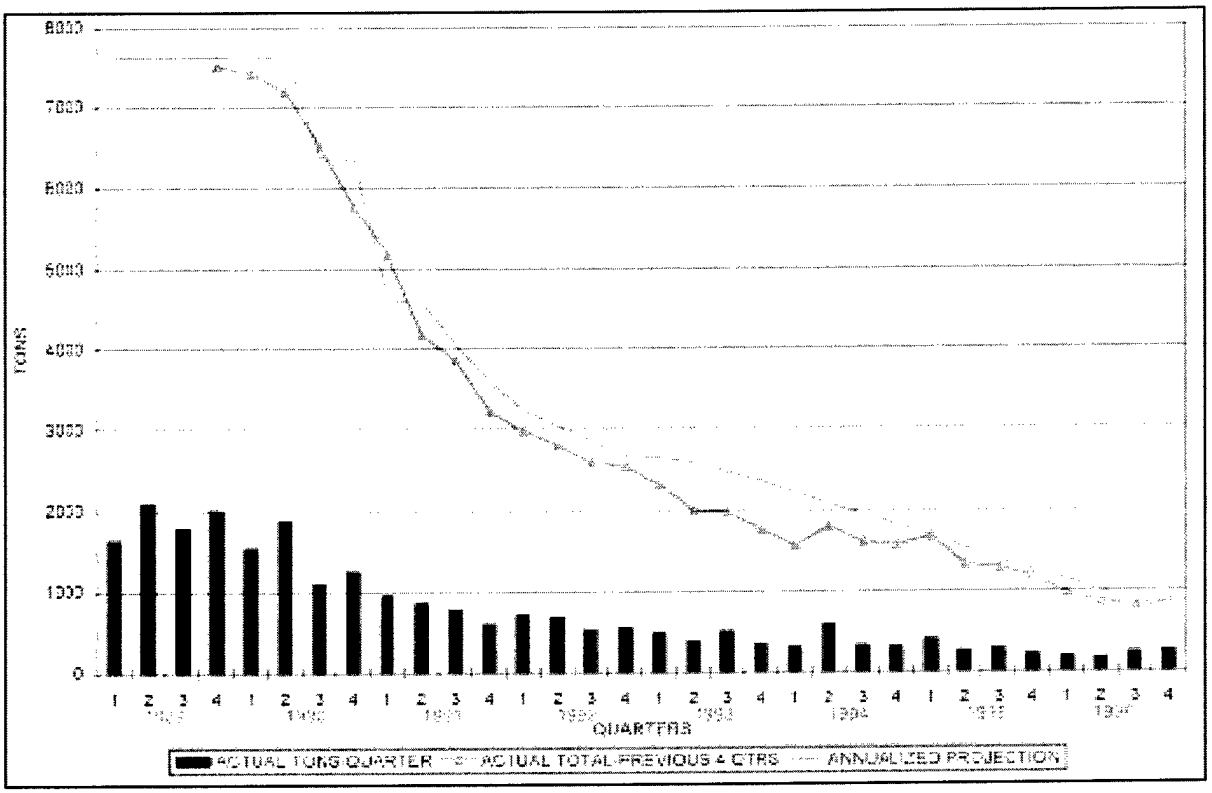


Figure 2-3. Hazardous Waste Reduction

Metrics are collected for performance measurement toward achieving goals, and the information is displayed in the Environmental Control Room. In addition, deficiencies identified during internal inspections and external audits are monitored; recurring hazardous waste and non-recurring hazardous waste are tracked (Figure 2-3); disposal and non-hazardous waste costs are watched; and reductions in toxic materials, volatile organic compound emissions, and ozone depleting chemicals are monitored. Since 1992, Northrop Grumman's environmental group has received 15 major awards for its efforts.

Environmental Training and Communications

In 1990, Northrop Grumman set an environmental goal requiring a 90% reduction in hazardous waste disposal by 1996. Management knew that environmental change would have to be practiced by all employees. The Command and Control method appeared to be the logical choice; however, early evidence indicated that this method would not work without a clear understanding and ownership of environmental needs by employees at the work floor level. In response, Northrop Grumman's Environmental Department created an excellent alternative using Focal Points (FPs).

FPs are employees on the work floor level who are identified, chosen, trained, and supported as important extensions to the Environmental Department. As the first points of contact and resident experts for a department's compliance, FPs ensure that each area has adequate and properly maintained pickup points for hazardous waste. Additional responsibilities include proper segregation of materials; acceptable containment vessels; correct labeling; pickup and delivery schedules; chemical usage tracking records management; and current training certifications for all area employees.

The Focal Point program has been extremely successful at Northrop Grumman. Employees chosen for FP duties must meet selected criteria including knowledge of a department's functions, processes, and personnel. This applicant must also possess the ability to communicate with both line personnel and members of management and, most of all, have the interest and desire to take on this added responsibility. In the beginning, there were 107 FPs throughout Northrop Grumman, but as line personnel and management acclimated to the new environmental attitude, the number was decreased to 25.

FPs are continually trained in process changes, and pass that message to the area employees. To assist the FPs, each process area in the facility has an Area Monitor (AM). AMs ensure that their process areas are in compliance at all times, and represent the voice of that area to the FPs. Northrop Grumman also uses many tools to maintain the environmental training needs of its employees. The key to this process is the FPs and AMs who train and inform the employees on environmental compliance. Techniques used include environmental training videos, uniform training packages, the Automated Documents and Manuals System, and quarterly meetings. Everyone can easily identify FPs and AMs for questions or concerns by the extra badge worn by these employees. The badge displays emergency and other important telephone numbers needed for environmental situations.

Northrop Grumman also created an awards and recognition program to recognize specific environmental excellence. Environmental Resources' senior management traditionally attends the awards ceremony to recognize employees or areas of zero deficiencies, Focal Point of the Year, and Hueso's Heroes. This type of positive exposure reinforces the efforts of Northrop Grumman's employees throughout the year.

In-House Air Toxics Modeling

Proposition 65 and the California Assembly Bill 2588 (AB2588) require industrial manufacturers that generate toxic air emissions to notify the public in the immediate area that there may be a risk of exposure to known carcinogenic substances. To comply with these regulations, Northrop Grumman's environmental engineers developed an In-House Air Toxics Modeling process to precisely determine the exact isopleth (the distribution and dispersion pattern of an airborne substance) of the toxic air emissions.

The modeling process consists of (1) identifying the pollutant sources and emission factors, (2) developing emissions inventories and public notification, (3) modeling, and (4) final analysis, presentation, and reporting. The modeling parameters include calculating the MICR using the following equation:

MICR = Q * (X/Q) * U * MP * MET, where Q is the emissions of pollutants in tons per year; X/Q is the dispersion factor as fn (distance from the emission source using Gaussian distribution calculations); U is the unit risk factor of toxic pollutant; MP is the multi-pathway factor of exposure (human toxicology); and MET are the meteorological factors.

A graphic model of the distribution and dispersion pattern of the toxic emissions can be generated for analysis, presentation, and compliance reporting by using standard Environmental Protection Agency (EPA) Industrial Source Complex Dispersion Models (ISC2 and ISC3); the California Air Resources Board Assessment of Chemical Exposure for AB2588; specialty software (Golden Software Surfer) developed expressly to calculate the isopleth; and sophisticated mapping software.

Northrop Grumman's In-House Air Toxics Modeling process determines accurate models that are essential for proper regulatory compliance. In addition, these models provide operational flexibility in program planning; reduce potential mitigation and related costs; and demonstrate a good neighbor policy with substantial and positive results.

Material Substitutions, Volatile Organic Compounds, and Air Toxics Reductions

In 1990, Northrop Grumman set a Corporate goal to reduce or eliminate air toxics and VOCs, and find environmentally-friendly (green) material substitutions for its manufacturing facilities in El Segundo, Pico Rivera, Palmdale, and Hawthorne. Figure 2-4

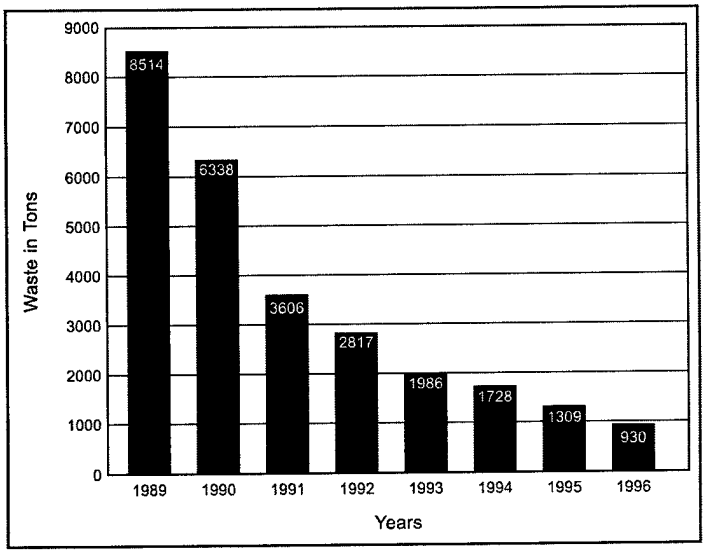


Figure 2-4. Air Toxics and VOC Reductions

shows that the company's 90% reduction goal was realized far ahead of its 1996 deadline. As part of this process, 80% of sealants used by Northrop Grumman were delisted to non-hazardous classification, resulting in a $230,000 cost savings for purchasing and disposal.

The Los Angeles Basin area, home to Northrop Grumman's facilities, historically has had the worst air quality in the Nation. The State of California and the EPA addressed this problem by tasking the SCAQMD with regulation of hazardous air pollutants (HAPs) and establishment of VOC emission standards. Through its forward thinking approaches like the 1990 Corporate goal, Northrop Grumman was able to meet SCAQMD's pollutant reduction mandates. The company designed and developed better control equipment (e.g., portable air pollution capture systems; HEPA filters on spray booths) and modified various processes to improve its coating application techniques including the HVLP spray gun (now the industry standard paint gun) and the specialty paint gun system for hard to reach areas. Through joint industry working groups, the company also adopted new environmental technologies from other aerospace companies. Another part of Northrop Grumman's overall initiative was its material substitution efforts and its reduction of HAPs and VOCs. The aqueous degreaser system, designed and developed in-house, eliminated vapor degreasers and some alkaline cleaners. Low chromium, cyanide-free conversion coating not only eliminates cyanide, but drastically reduces chromium in the process. Other processes that helped achieve the Corporate goal were the automated paint mixing system for touch-ups; electrostatic/ powder coating process; on-demand paint mixing; two-component paint dispensing systems; paint gun solvent recovery system; and work in process cans. All played a part in the 77% reduction of air toxics which the company attained in 1995.

Reducing hazardous waste, as well as employee and community exposure to these materials, are part of Northrop Grumman's philosophy. The company notes that it uses innovation and technology to find solutions to environmental challenges as the need to assume greater responsibility for the environment becomes increasingly important. Through its forward thinking and proactive environmental approaches, Northrop Grumman operates as a responsible company and a good neighbor to the surrounding community.

Plural Component Paint Dispensing for Touch-Ups

Primers applied to aircraft generally consist of two/three-component, catalyzed, corrosion-inhibiting, epoxy polyamide products. The primer process requires specific proportioning of each component plus proper mixing. Mixing instructions are based on the assumption that these products will be used in a spray application. Water reducible primer formulated for spraying causes problems when used in a brush touch-up application. The low viscosity of the spray grade primer produces sags and runs, and does not cover the sealant, fasteners, and scratches as required.

Northrop Grumman selected Sealant Equipment and Engineering's See-Flo 387 equipment (Figure 2-5) to meter, mix, and dispense primer in sizes suitable for touch-ups. Characteristics of the unit include:

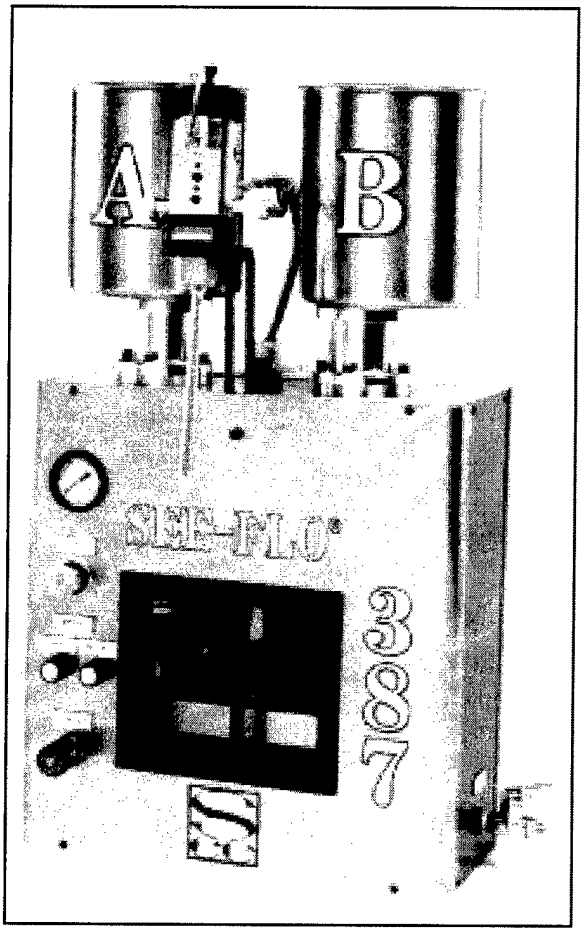


Figure 2-5. Plural Component Mixing and Dispensing System

- Precision metering
- Components are kept separate prior to entering the mix chamber
- Components are held in pressure pot reservoirs or gravity feed hoppers
- Adjustable dispensing of material
- Operable by push buttons on the control panel or by foot pedals
- No-drip nozzle assures that the dispensing tip does not drip paint after each dispense cycle

The cycle time for this unit is less than ten seconds. Hundreds of one-half- to two-ounce batches of ready-to-apply primer can be dispensed into touch-up plastic bottles and made available to Northrop Grumman's assembly workers in a very short time.

The assembly workers also needed a brush grade primer which met all the requirements of a spray grade primer, but with more viscosity. This product had to be a ready-to-use item that did not require proportioning, mixing, or reliance on another organization to supply or mix the primer. Northrop Grumman worked with Deft Coatings, Inc. to produce a touch-up water reducible primer formulated for brushing. The resulting primer is specification approved for military and commercial programs; works in plural component dispensing systems; and can be packaged in three-component kits, usually in one- to two-ounce sizes.

Advantages of Plural Component Paint Dispensing kits are:

- The three components are proportioned, mixed, and dispensed by the system instead of an individual.
- Hundreds of one-half- to two-ounce batches of mixed, ready-to-apply primer can be obtained in less than an hour.
- The system can be flushed and cleaned with water.
- Only one container is used for disposal.

Disadvantages of off-site purchased, three-component kits are:

- Three separate components need to be manually mixed to produce one ounce of primer.
- Shaking the components excessively reduces the pot life, while insufficient mixing produces a non-acceptable finish.
- High cost associated with off-site purchased kits.
- Three separate components per kit produce an abundance of hazardous waste containers for disposal.

Purchasing three-component primer kits from outside vendors costs $96,000 per year. By producing the Plural Component Paint Dispensing kits in-house, Northrop Grumman spends only $25,000 per year for a net savings of $71,000. Total investment cost for the equipment needed to produce the in-house primer kits was $30,000. The company recouped its investment cost in approximately 106 days.

Plural component metering, mixing, and dispensing for touch-up primer is an alternative to buying touch-up kits from an outside vendor. Northrop Grumman evaluated various factors prior to its decision including total costs from outside vendors versus in-house equipment and labor costs; and the volume of material used per application. In the case of producing touch-up quantities of water reducible primer, the advantage is clearly in favor of purchasing equipment and dispensing the material, rather than buying kits from an outside vendor.

Pollution Prevention and Reductions

Previously, Northrop Grumman was spending nearly $7 million to dispose of its 7,500 tons of hazardous waste. In 1990, Northrop Grumman set an aggressive environmental Corporate goal (using a 1989 baseline) to achieve a 90% reduction in hazardous waste disposal by 1996. Based on its reputation for solving complex problems with advanced technology and sophisticated engineering, Northrop Grumman challenged its employees to meet this goal. As a result, employees utilized their talents and not only achieved this goal but, in many cases, surpassed the goal by 1996. The Environmental Department focused on reducing employee and community exposure; operational costs; and Corporate liability. Several approaches used to achieve these pollution prevention objectives included changing the processes or equipment; substituting chemicals; eliminating hazards; and reducing toxicities and emissions. Alternatives such as recycling and reuse were chosen for some of the spent chemicals, while in some cases neutralizing the chemical prior to disposal was the only option. The Department also created and maintained an aggressive schedule in the environmental control room to prioritize individual projects quarterly through 1996.

Research revealed several equipment options that would assist Northrop Grumman in pollution prevention throughout its operations. Key equipment changes included:

- On-demand, multi-component paint dispensing machines to reduce the amount of paint purchased for touch-ups as well as excess waste generation
- Creation of PAPCE to reduce emissions from touch-up spraying
- Specialized HEPA filter banks on paint booths to reduce chromate emissions
- Replacement of photographic chemistry with electronic imaging
- Replacement of air agitation with eductor-assisted fluid agitation
- Use of solvent distillation to aid in solvent recovery
- Replacement of large, wasteful, open-topped solvent tanks with enclosed spray gun cleaning machines
- Creation of specialized tables to limit the amount of alodine wasted during specific touch-ups
- Replacement of chromate processing chemicals with non-chromated equivalents

The company's push for reductions in ODCs and VOCs combined with these equipment changes resulted in an 89% reduction in hazardous waste by 1996. By surpassing the environmental Corporate goal and obtaining the 89% hazardous waste reduction in only six years, Northrop Grumman's leaders and employees felt they could do even better. A new goal was established to eliminate 50% of the remaining hazardous waste by the year 2001. Several equipment ideas continue to be perfected. One employee-suggested idea was to furnish each workstation with a Work-In-Process (WIP) can. These metal WIP cans have a lid to keep rags/gloves clean and damp for reuse throughout the day. Earlier practices required the rags to be disposed of as hazardous waste after each use because there was no place to store the rag for reuse. WIP cans provide Northrop Grumman with an annual savings of $200,000. The company also uses many sealants during the manufacturing process, and close observation identified tremendous waste from unused sealants. Northrop Grumman reduced this waste by changing from six-ounce tubes to one- and two-ounce tubes for use in small jobs. This practice has been well supported by the employees and decreased waste at the facilities.

In the 1990s, Northrop Grumman took aggressive steps toward reducing non-hazardous solid waste at all its facilities as well. Several recycling bins were scattered across the facilities to accommodate a recycling program. Employee attitudes blended well with this program as most employees were accustomed to recycling at home. During recycling market fluctuations, Northrop Grumman identified the least expensive method for continuing its non-hazardous waste recycling program. The effort resulted in the company switching from a source separation and collection method to a bulk collection method of non-hazardous waste which is then sorted at an off-site Materials Recovery Facility (MRF). Metrics collected from the MRF maintain the integrity of the program. Table 2-1 shows the metrics for the West Complex in 1997. Northrop Grumman also identified an outlet for its wood waste through a vendor who grinds the wood and forms it into

Table 2-1. Diverted Non-Hazardous Waste

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Tons Recycled
Plastic & Glass	0.44	0.86	0.34	1.22	0.69	1.11	0.62	0.37	0.80	0.81	0.30	0.64	8.20
Paper	9.16	10.27	7.87	5.17	7.25	7.05	5.84	7.82	9.64	8.91	9.15	5.55	93.68
Wood	23.99	22.68	19.50	18.25	20.02	21.89	17.84	22.33	22.49	22.66	12.70	9.81	234.16
Metal	2.18	2.56	1.37	0.91	1.73	1.48	1.23	1.12	1.61	2.04	2.36	0.00	18.59
Cardboard	7.85	6.42	5.13	4.87	4.83	5.58	5.23	5.58	5.62	6.06	5.02	5.33	67.52
Total Tons Picked Up:	131.30	123.80	106.20	108.64	113.20	118.96	111.37	134.43	131.07	132.97	94.35	96.76	1,403.05
Total Tons Recycled:	43.62	42.79	34.21	30.42	34.52	37.11	30.76	37.22	40.16	40.48	29.53	21.33	422.15
Total Tons Landfilled:	87.68	81.01	71.99	78.22	78.68	81.85	80.61	97.21	90.91	92.49	64.82	75.43	980.90
Diversion Percentage:	33.22%	34.56%	32.21%	28.00%	30.49%	31.20%	27.62%	27.69%	30.64%	30.44%	31.30%	22.04%	30.09%

fireplace logs. Other materials such as excess paint, office supplies, and laboratory equipment are continually donated by the company to local schools and not-for-profit organizations.

Smaller Sealant Tubes

Northrop Grumman has achieved an 89% reduction in hazardous waste since 1990 by several equipment and chemical replacements. Many simple ideas support the overall waste minimization goal and, at the same time, save money for the company. One such idea was smaller sealant tubes which resulted in an annual savings of $70,000.

At Northrop Grumman, sealants are used throughout the manufacturing process when bonding various detail parts to larger assemblies, or to ensure additional strength of any given part. Due to various process specifications, some sealants must be frozen until needed; others have a limited shelf life; and a variety of sealants need to be mixed prior to use. Customer specifications for sealants must meet very strict guidelines for use and cannot be changed without written approval.

Vendors who supply sealants to Northrop Grumman were requested to repackage their product in one- and two-ounce tubes instead of the previously used six-ounce tubes. The smaller tube sizes enabled Northrop Grumman to generate less waste and reduce the number of containers disposed as hazardous waste. Since only the packaging was changed, customer approval was not needed.

After implementing the packaging change, Northrop Grumman's sealant waste generation was reduced by 30%. Operators indicate that the smaller tubes are easier to handle, require less storage space, and reduce the overall amount of waste generated. This change has enabled Northrop Grumman to achieve an annual 20,000-pound source reduction on the amount of material purchased and waste produced.

Work-In-Process Cans

Some of the best ideas for a company to save money come from its employees on the work floor. One successful idea was to furnish each workstation with a Work-In-Process (WIP) can. In 1991, the company implemented this idea at its Hawthorne and El Segundo facilities.

WIP cans (Figure 2-6) are temporary storage, closed top, metal cans that measure approximately 12 inches in diameter and seven inches deep. Wiping rags, shop towels, and rubber gloves can be temporarily stored in the cans and reused throughout the work shift. The cans are then emptied at the end of each shift.

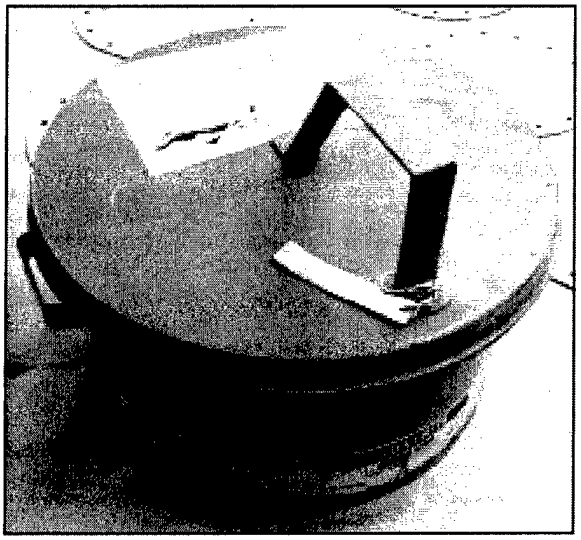


Figure 2-6. Work-In-Process Can

WIP cans extend the useful life of rags, towels, and gloves; decrease the amount of solvent used; and reduce the number of hazardous waste containers for disposal. Northrop Grumman has realized an annual cost savings of $200,000 since implementing WIP cans. Worker efficiency has also improved by placing WIP cans throughout the facility. Employees have less contaminated materials to discard, and make fewer trips to the hazardous waste containers. This method has proven feasible in reusing textiles for those jobs which do not require a high degree of cleaning. Any operations facility that uses VOC-containing materials on wiping rags, shop towels, and/or rubber gloves could benefit from this simple-to-implement program.

Management

Chemical Tracking System

In 1991, Northrop Grumman realized that its existing system was not efficient at tracking chemicals within the company. Management decided to update to an electronic, cradle-to-grave system which would be accessible throughout the facility. Placed on-line in 1992, Northrop Grumman's Chemical Tracking System (CTS) contains components, sub-

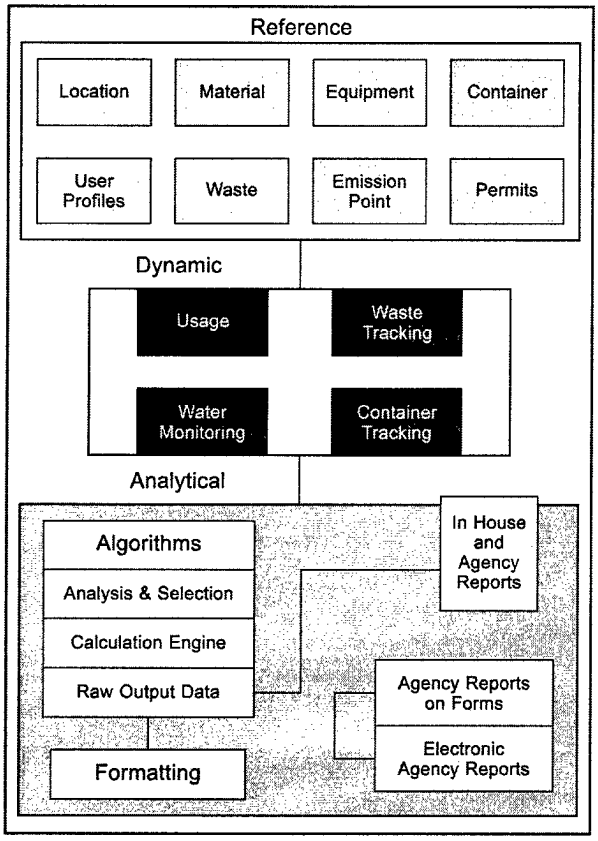


Figure 2-7. Chemical Tracking System Architecture

components, and reference data. The architecture of the CTS is shown in Figure 2-7.

The CTS was developed with off-the-shelf software, configured specifically for Northrop Grumman, and runs on a mainframe. The system can interface with other systems, and is user-friendly so floor personnel can perform updates on a chemical's location and usage. The three systems that interface (Figure 2-8) with the CTS are:

- Chemical Review Board — Controls which chemicals can be purchased and how these chemicals are used.
- Totally Integrated Procurement System — Purchases only approved chemicals.
- Material Safety Data Sheet (MSDS) Imaging and Faxback — Contains more than 8,100 MSDSs; allows the user to select documents and receive copies via facsimile.

Northrop Grumman's CTS works as a closed-loop system for tracking chemicals from initial request through location, use, and reporting. The system currently collects approximately 100,000 records

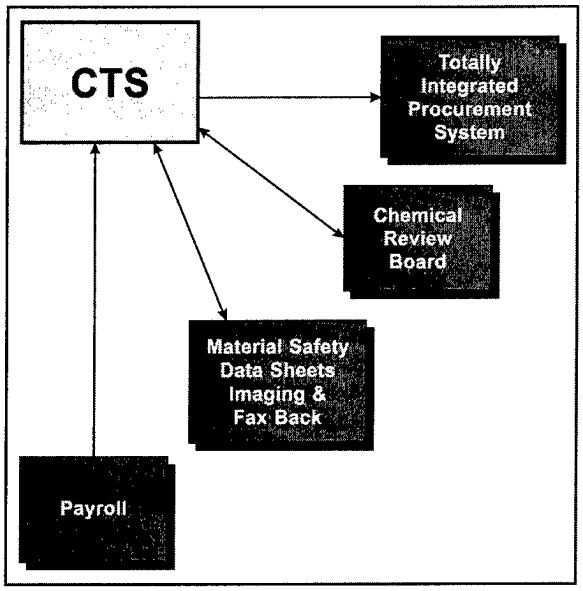


Figure 2-8. Chemical Tracking System Interfaces

per year, and operates as the prime instrument to create more than 250 reports annually. Northrop Grumman also uses the system to gauge its progress of waste and toxic reduction efforts; and track its permits and agency requirements for approximately 700 regulated processes and equipment.

Environmental Inspection Program

Northrop Grumman has an extensive internal Environmental Inspection Program designed to ensure 100% compliance with all regulatory requirements, and reduce emissions and environmental hazards. Inspection teams make regular periodic inspections of all work areas and facilities. A re-inspection is conducted ten days after every inspection to ensure that discrepancies noted on the initial inspection were corrected. These follow-up inspections are conducted even if no discrepancies were observed on the initial inspection, and serve as a double check for the company.

Northrop Grumman has five inspection teams consisting of one inspector per team. Since a small number of people must cover a large number of work areas and facilities, the company automated many aspects of the inspection process to speed up the procedure and eliminate paperwork. Inspectors complete checklists via personal workstations, and the inspection reports are then generated automatically. More time can be devoted to inspecting and

correcting discrepancies rather than writing them up. The automated checklists also serve as an effective way to prompt inspectors, ensuring a thorough, complete, and consistent inspection every time. Most discrepancies are easy to correct, and are typically corrected when noted.

For 1998, Northrop Grumman set a maximum threshold goal of 0.5 for major environmental deficiencies per inspection. It is important to keep this threshold as low as possible because each deficiency represents a potential fine of $50,000 or more per deficiency per day. Since the Environmental Inspection Program has been in effect, the average number of major deficiencies per inspection has been reduced each year. This program has been highly effective in ensuring that Northrop Grumman avoids non-compliance costs, and also helps to keep the company in high regard by the regulatory enforcement personnel.

Legislative and Regulatory Involvement

As one of the largest manufacturers in the southern California region, Northrop Grumman found that proactive involvement is essential in the environmental regulatory and rule making process. This region is one of the most regulated and environmentally restrictive parts of the country for manufacturers. Northrop Grumman learned early on that the regulatory agencies did not have a good understanding of the aerospace industry, and thus the company has taken an active role in rule development for many years. Only by companies working with regulators can rules be adopted that achieve the intended goals, but not be overly burdensome.

Northrop Grumman has a broad array of regulatory agencies which it must satisfy in addition to the federal EPA. California state regulatory agencies include the California Environmental Protection Agency; the Air Resources Board; the Department of Toxic Substance Control; the Office of Health Hazard Assessment; the Water Resources Control Board; and the Integrated Waste Management Board. Local environmental agencies include SCAQMD; the Antelope Valley Air Pollution Control District; the Mojave Desert Air Quality Management District; the Certified Unified Permitting Agency; and regional water quality control boards. In general, the regulatory requirements of the state, regional, and local agencies are more stringent than federal EPA requirements (e.g., regional regulations on chromium are 12 times more stringent than EPA regulations). Rather than stand alone against this formidable array of regulatory agencies, Northrop Grumman formed alliances and partnerships with various industry groups. The company is a member of the Southern California Air Quality Alliance which is a unit of the California Manufacturers Association. Another is the Regulatory Flexibility Group, a diverse group of about 14 major manufacturers in the region that is active in influencing regional regulatory requirements and issues. Northrop Grumman is also an active member of the California Aerospace Environmental Association, and participates on various industry ad hoc committees that are formed to work on specific regulatory implementation issues. The company also retains an environmental lobbying firm in Sacramento to give it a voice in shaping proposed legislation affecting the aerospace industry in California.

These alliances and relationships have helped the company deal with a variety of issues including adoption of the Regional Clean Air Incentives Market (RECLAIM) rules; air toxic control regulations for new and existing sources; new aerospace coatings and solvents rules; and the new federal Title V Operating Permits Program for emitting and potentially emitting sources. In the case of the RECLAIM rules, all of the industry groups in which Northrop Grumman participates took a proactive approach to these rules, primarily dealing with the combustion of fuels. Group leaders from the various organizations actively worked with top-level SCAQMD management. Personnel from Northrop Grumman participated in the agency rule-making process including advisory committees, working groups, and public workshops. Northrop Grumman and industry group representatives met regularly with rule-making staff members to tour facilities, provide technical data, participate in pilot programs, and review and comment on proposed rule drafts. This approach helped Northrop Grumman win realistic NO_x and SO_x allocations based on past productivity and equipment requirements for individual facilities. In addition, the company successfully communicated to the regulatory agencies that proposed VOC requirements were too low and had excessively burdensome reporting requirements. Other accomplishments included extending the compliance date for reducing the VOC content of 250°F cure adhesive bonding primer from 805 to 250 grams per liter in light of the fact that compliant primers were not available.

Many new challenges face Northrop Grumman and the aerospace industry in the coming years. By taking a proactive approach, working with the regulatory agencies, and educating regulators about unique aerospace requirements and concerns, Northrop Grumman developed a very effective approach to protecting the environment responsibly while maintaining its competitive position and the quality of its products.

Leuzinger High School Environmental Academy Partnership

The Leuzinger High School Environmental Academy Partnership is one of Northrop Grumman's good neighbor projects. As a participating member of the community, Northrop Grumman chose to invest time, manpower, and money in a partnership with the California Department of Education to further the environmental education experience, and expand the knowledge of local at-risk high school students.

Established in 1996, the Environmental Academy Partnership program is geared specifically toward at-risk students to encourage them to stay in school and broaden their educational horizons and goals. Students must apply to be accepted into the program. Criteria for acceptance is based on student commitment; demonstrated improvement in school attendance and grades; and parental involvement. In return, students gain basic job preparation skills; resume writing and building; development of interviewing skills; self improvement; teaming; public speaking; higher education credits and goals; and guidance toward becoming a valuable and productive community member.

During the first year, 60 students met the criteria and were accepted into the program. The following year, the application list grew to 100 candidates. Northrop Grumman's participation goes beyond hosting environmental training for the students. Efforts by the company include working with teachers to develop environmental program curricula; participating in career day events at the high school; giving briefs and plant tours to teachers and students; and donating supplies, laboratory glassware, and money at the local and corporate levels.

Northrop Grumman's involvement and commitment to the community are demonstrated by projects such as the Leuzinger High School Environmental Academy Partnership. In addition, the company and its employees are making a difference by investing in the people from their community.

Title V Operating Permits Program

Northrop Grumman's Environmental Resources Department implemented a very proactive process to minimize the negative effects of Title V regulations. The company incorporated an internal, user-friendly network that generates reports necessary for Title V compliance. Northrop Grumman's effort, along with careful, long term permit projections, will enable the company to operate in full compliance within the stringent California regulations.

The Title V amendment of the Clean Air Act is a federally-operated permitting program administered by EPA-approved state programs. The increased monitoring, record keeping, and reporting elements contained in this program make it one of the most intensive air regulations to date. The program also requires mandatory self-reporting of non-compliance, and is enforceable by the EPA and citizens' suits. A key aspect of Title V is that it consolidates all air quality requirements to a single, five-year plan for a contiguous facility. Therefore, planning and projection are critical to having a comprehensive permit submission because the lengthy revision process can take up to two years to work its way through the system. Public notification and approval by local agencies as well as the EPA are also requirements of the revision process. The forecasting of these delays and the effective planning for future production requirements are excellent models for other aerospace companies.

Northrop Grumman's previous system did not have environmental provisions for new projects, and relied on the design review approval process to identify equipment which needed permits. This often led to delays in projects and put schedules at risk. In addition, the equipment permits and related data were maintained in manual files. The company's new system provides source-by-source linkage with existing emission and equipment data; standardizes reports which are expandable to new requirements; and provides real-time data of hazardous waste usage and emission streams. The system also integrates an AOP and quarterly surveys to obtain early warnings of potential environmental impacts. The AOP centralizes plans and potential projects from Northrop Grumman's operating elements, and has become the mechanism for communicating environmental requirements to program planners and engineers throughout the company. An effective tool developed to gather this information was the Environmental Planning Checklist which identifies such areas as equipment

using hazardous materials or generating fumes; alteration of exhaust ventilation systems or sewer connections; anticipated changes in production rates; and closure of an existing facility.

Already planning for the difficult process of obtaining amendments to the Title V permit, the Environmental Organization has secured flexible permits which will meet production requirements into the foreseeable future. Early comprehensive permitting for the new F/A-18 E/F Painting Technology Facility allows construction of seven paint booths and associated boilers. This permitting will allow a variety of processes to be utilized in the aerospace industry while maintaining compliance to VOC emissions within the existing cap. Other particulars include allowing for phased construction as needed; providing for production expansion and business diversification; and using existing emission allowances.

To process and organize data required to complete reports necessary for Title V permitting, Northrop Grumman utilizes its Chemical Tracking System (CTS). This system incorporates a chemical review process of hazardous chemicals, provides procurement controls, inspection programs, chemical tracking, and remote metering of critical hazardous equipment. The CTS has been an instrumental tool in achieving pollution prevention objectives. In addition, the system also maintains regulatory compliance records, prevents unauthorized use of chemicals, and provides data for reporting taxes and fees.

The costs of early permitting are very minimal compared to those associated with schedule delays. Northrop Grumman's proactive permitting process, along with the visions and preparations put forth by the Environmental Organization, have positioned the company as a leader in environmental compliance for the aerospace industry.

Water Quality Improvement Practices

Northrop Grumman's Environmental Resources Department is responsible for soil and water quality. This group's responsibilities include management of the facility's water quality program elements including wastewater discharge control; inspections; equipment maintenance; water quality sampling and data management; permit reviews; facilities design reviews and coordination; and regulatory compliance reviews. Several process improvements have been implemented which significantly improved the company's wastewater management, compliance, and cost.

Although wastewater discharges were compliant 90% of the time, a program was initiated to eliminate uncontrolled discharges of rinse water into the sewer system. Approximately 10% of the time, contaminants in the water exceeded allowable discharge limits (e.g., small amounts of chrome and/or low pH levels). A pre-treatment plant existed at a nearby Northrop Grumman site, but installation of an underground transfer line was neither cost effective nor feasible. Installation of a new pre-treatment plant for the remaining 10% would cost $500,000 plus significant recurring cost. Besides being cost ineffective, this idea would impact the production schedule. The solution was to collect wastewater in holding tanks where it could be tested before discharge. Most of the time, the water is acceptable for discharge into the sewer, and can be released by opening a valve. If necessary, pH levels can be adjusted in the holding tank before releasing the water. Any non-compliant water is drained from the tanks and taken to the nearby pre-treatment facility by truck. The reduction of capital cost from $500,000 to less than $100,000 to install control equipment and minimal recurring cost resulted in a significant savings and avoidance of inadvertent discharges and potential liability. Since implementation, wastewater discharge control has been 100% effective and no violations have occurred.

Another improvement resulted when Environmental Resources began getting involved in the early phases of new construction projects undertaken by the Facilities Department. Previously, Environmental Resources would request changes to meet regulatory requirements after the construction projects had been completed. This approach increased the cost of construction projects and jeopardized wastewater compliance status. The new process requires involvement and consultation with Environmental Resources during the planning stages of all construction projects. A wastewater specification sheet was developed for planners to identify wastewater design requirements. This improvement decreased the discrepancies found in the review and approval of design drawings; reduced changes to wastewater installations during field inspections; and lowered the cost of construction projects.

Northrop Grumman also operates clarifiers that remove sludge from wastewater and other liquids. Over a long period of time, sludge which collects in a clarifier's holding tank can sometimes meet the definition of hazardous waste. Due to the local environmental authorities' interpretation that clarifiers are actually containers holding hazardous

waste, Northrop Grumman would need to clean its clarifiers every 90 days at a cost of $60,000 per year. This interpretation would significantly increase the costs and amount of hazardous waste at Northrop Grumman. To eliminate this problem, Environmental Resources implemented a procedure to sample the sludge every 90 days. If the sludge meets the definition of hazardous waste, then the clarifier is cleaned. If it does not meet the definition, no action is taken. As a result, cleaning the clarifiers is only required about every two years or more. The procedural change was successful in reducing over 90% of clarifier sludge disposal and corresponding cleaning costs.

Section 3

Information

Facilities

Electronic Natural Gas Metering System

Northrop Grumman has reduced operating costs by installing an Electronic Metering System for its eight natural gas boilers. This system analyzes gas flow rates and usage for remotely located boilers, and then transmits the information to a central computer. Previously, the data collection was accomplished by meter readers who would gather this information on a monthly basis. The manual system involved significant work hours, and did not provide real-time snapshots of gas usage. This information is necessary for obtaining operating permits in the stringent southern California region.

A turbine meter, installed at each boiler, provides engineers with gas usage amounts which are then automatically calculated into emission rates. The Electronic Monitoring System can track the dynamic emission discharges in either real-time, hourly, monthly, or annual modes. The reports generated by the system validate compliance of the facilities to the local air quality management inspectors.

SCAQMD regulates the local air quality, and sets standards up to 12 times greater than those set by the EPA. To accomplish this goal, SCAQMD provides incentives to its 353 participating sites through the RECLAIM program. As the world's largest emissions trading market program, RECLAIM offers flexibility to local facilities in reducing their NO_x and SO_x emissions.

Management

Chemical Review Board

In 1994, Northrop Grumman created the Chemical Review Board (CRB) to evaluate hazardous material and ensure compliance to federal, state, and local regulations. The CRB was interfaced into the existing On-line Purchasing and Chemical Tracking Systems. Although predominantly an electronic process, the review cycle still has a manual element which involves the CRB Committee (comprised of personnel from Air Quality; Health & Safety; Fire Department; and Pollution Prevention). Northrop Grumman is currently changing the manual part of the cycle into an entirely electronic process which will improve turnaround time.

Under the current system, the requester fills out a Chemical Review Survey Form and forwards it to the CRB. The CRB prepares a package (containing the CRB Worksheet, the Purchase Requisition, the Chemical Review Survey Form, the MSDS, and the Air Quality Management 109 Certification Form) and forwards a hard copy to the CRB Committee. Once the Committee reviews it and adds input, the package is returned to the CRB who distributes the information to the requester, updates the On-line Purchasing System, and scans the MSDS into the LAZERFICHE Imaging System for retention.

The new system will eliminate the hard copies and perform all the functions electronically. Once the request is received by the Chemical Review Administration, they will load the request into the CRB Data Repository, scan the documents into a new document management system, EZPOWER, and electronically forward it to the CRB Committee. The Committee will provide input and electronically return it to the Chemical Review Administration who then notifies the requester and loads the information into the Chemical Tracking System.

Northrop Grumman's current turnaround time is approximately four days. Once the new system is implemented (May 1998), the company's goal is for a two-day turnaround with cost savings in hard copies and work hours.

The new CRB Data Repository is a dynamic relational database, with various pull-down menus that promote data accuracy with consistency between CRB, CTS, and EZPOWER. Additional features which have not yet been utilized are:

- Reporting capabilities;
- Retention of historical data;
- Web enabled;
- Access to MSDSs on the Intranet; and
- Approval status on the hazardous materials.

Appendix A

Table of Acronyms

Acronym	Definition
AB2588	California Assembly Bill 2588
AM	Area Monitor
AOP	Annual Operating Plan
CRB	Chemical Review Board
CTS	Chemical Tracking System
EPA	Environmental Protection Agency
FP	Focal Point
HAP	Hazardous Air Pollutant
HEPA	High Efficiency Particulate Arrester
HexCr	Hexavalent Chromium
HVLP	High Volume, Low Pressure
MASD	Military Aircraft Systems Division
MICR	Maximum Individual Cancer Risk
MRF	Materials Recovery Facility
MSDS	Material Safety Data Sheet
ODC	Ozone Depleting Chemical
PAPCE	Portable Air Pollution Control Equipment
RECLAIM	Regional Clean Air Incentives Market
SCAQMD	South Coast Air Quality Management District
VOC	Volatile Organic Compound
WIP	Work-In-Process

Appendix B

BMP Survey Team

Team Member	Activity	Function
Larry Robertson (812) 854-5336	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Chairman**
Cheri Spencer (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**
	Team 1	
Rick Purcell (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
Mark Hancock (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Elaine Geisler (909) 273-4991	**Naval Warfare Assessment Division** Corona, CA	
	Team 2	
Darrel Brothersen (319) 295-3768	**Rockwell Collins Avionics & Communications** Cedar Rapids, IA	**Team Leader**
Yvonne Lach (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Tim Hanley (425) 342-5322	**The Boeing Company** Seattle, WA	

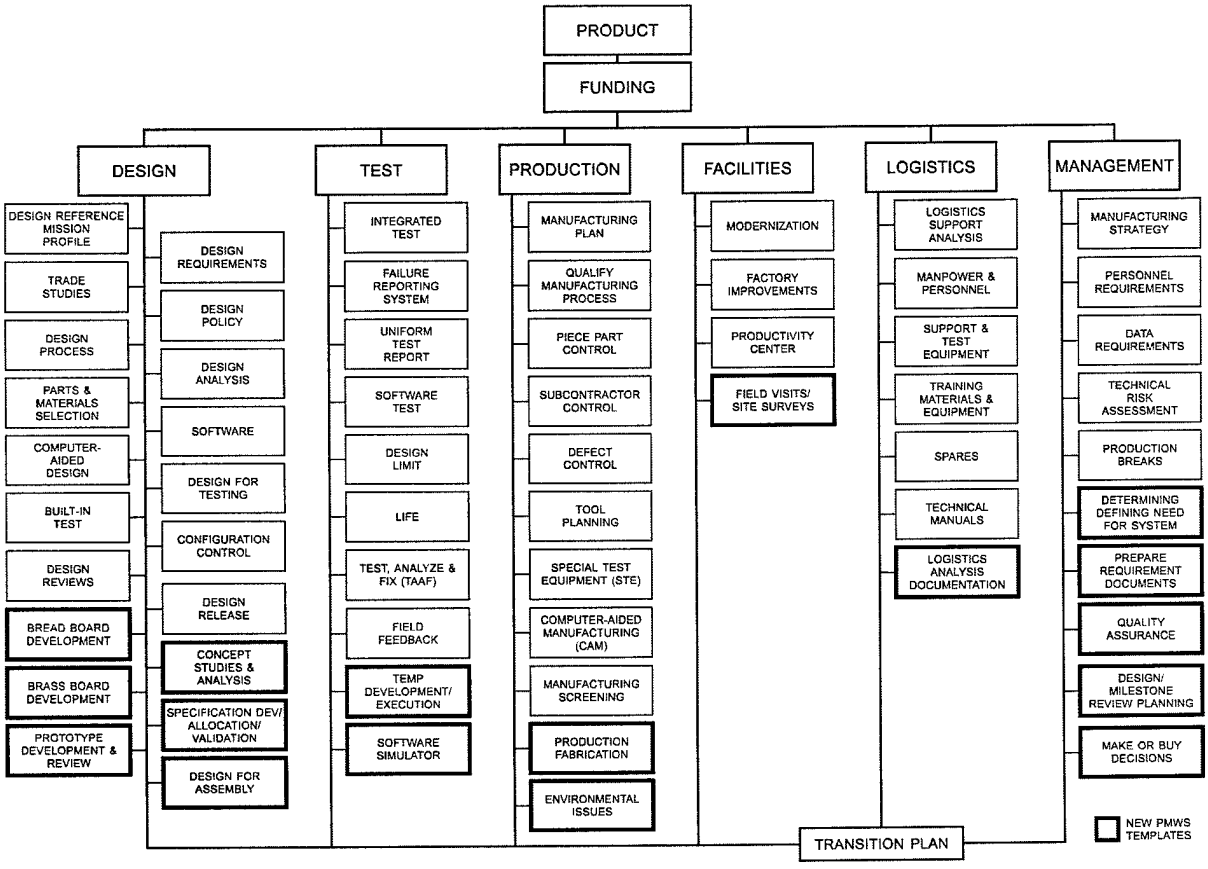
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

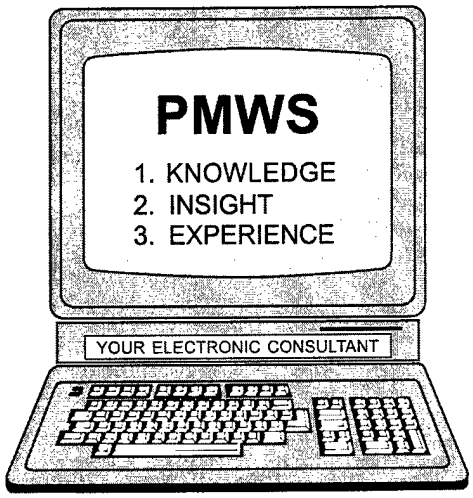
"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D

BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at http://www.bmpcoe.org), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.



PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.

KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition personnel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at http://www.bmpcoe.org. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently eight Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The eight BMP satellite centers include:

California

Chris Matzke
BMP Satellite Center Manager
Naval Warfare Assessment Division
Code QA-21, P.O. Box 5000
Corona, CA 91718-5000
(909) 273-4992
FAX: (909) 273-4123
cmatzke@bmpcoe.org

Jack Tamargo
BMP Satellite Center Manager
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
FAX: (707) 642-4267
jtamargo@bmpcoe.org

District of Columbia

Chris Weller
BMP Satellite Center Manager
U.S. Department of Commerce
14th Street & Constitution Avenue, NW
Room 3876 BXA
Washington, DC 20230
(202) 482-8236/3795
FAX: (202) 482-5650
cweller@bxa.doc.gov

Illinois

Thomas Clark
BMP Satellite Center Manager
Rock Valley College
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5515
FAX: (815) 654-4459
adme3tc@rvcux1.rvc.cc.il.us

Louisiana

Dr. Kenneth L. McManis
Director
Maritime Environmental Resources & Information Center
Gulf Coast Region Maritime Technology Center
University of New Orleans
810 Engineering Building
New Orleans, LA 70149
(504) 280-6271
FAX: (504) 280-5586
klmce@uno.edu

Michigan

Maureen H. Reilly
SAE/BMP Satellite Center Manager
3001 W. Big Beaver Road, Suite 320
Troy, MI 48084-3174
(724) 772-8564
FAX: (724) 776-0243
reilly@sae.org

Roy T. Trent
SAE/BMP Automotive Manufacturing Initiative Manager
3001 W. Big Beaver Road, Suite 320
Troy, MI 48084-3174
(248) 652-8461
FAX: (248) 652-8662
bounder@ees.eesc.com

Pennsylvania

Sherrie Snyder
BMP Satellite Center Manager
MANTEC, Inc.
P.O. Box 5046
York, PA 17405
(717) 843-5054, ext. 225
FAX: (717) 854-0087
snyderss@mantec.org

Tennessee

Tammy Graham
BMP Satellite Center Manager
Lockheed Martin Energy Systems
P.O. Box 2009, Bldg. 9737
M/S 8091
Oak Ridge, TN 37831-8091
(423) 576-5532
FAX: (423) 574-2000
tgraham@bmpcoe.org

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
rfglcc@glcc.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
Plymouth Executive Campus
Bldg 630, Suite 100
630 West Germantown Pike
Plymouth Meeting, PA 19462
(610) 832-8800
FAX: (610) 832-8810
http://www.engriupui.edu/empf/

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing

productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

Manufacturing Science and Advanced Materials Processing Institute

The Manufacturing Science and Advanced Materials Processing Institute (MS&AMPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&AMPI:
Mr. Henry Watson
Manufacturing Science and Advanced Materials Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-6345
FAX: (814) 863-1183
hew2@psu.edu

- **National Center for Advanced Drivetrain Technologies**
  The NCADT supports DoD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

  Point of Contact for NCADT:
  Dr. Suren Rao
  NCADT/Drivetrain Center
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-3537
  FAX: (814) 863-6185
  http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

  The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

  Point of Contact for SEMTC:
  Dr. Maurice F. Amateau
  SEMTC/Surface Engineering Center
  P.O. Box 30
  State College, PA 16804-0030
  (814) 863-4214
  FAX: (814) 863-0006
  http://www/arl.psu.edu/divisions/arl_org.html

- **Laser Applications Research Center**

  The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

  Point of Contact for LaserARC:
  Mr. Paul Denney
  Laser Center
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-2934
  FAX: (814) 863-1183
  http://www/arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

Appendix G

Completed Surveys

As of this publication, 103 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA
	Norden Systems, Inc. - Norwalk, CT
	Naval Avionics Center - Indianapolis, IN
	United Electric Controls - Watertown, MA
	Kurt Manufacturing Co. - Minneapolis, MN
	MagneTek Defense Systems - Anaheim, CA
	Raytheon Missile Systems Division - Andover, MA
	AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ
	Resurvey of Texas Instruments Defense Systems & Electronics Group - Lewisville, TX
1992	Tandem Computers - Cupertino, CA
	Charleston Naval Shipyard - Charleston, SC
	Conax Florida Corporation - St. Petersburg, FL
	Texas Instruments Semiconductor Group Military Products - Midland, TX
	Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA
	Watervliet U.S. Army Arsenal - Watervliet, NY
	Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA
	Computing Devices International - Minneapolis, MN
	(Resurvey of Control Data Corporation Government Systems Division)
	Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL
	Naval Aviation Depot Naval Air Station - Jacksonville, FL
	Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN
	McDonnell Douglas Aerospace - Huntington Beach, CA
	Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY
	Philadelphia Naval Shipyard - Philadelphia, PA
	R. J. Reynolds Tobacco Company - Winston-Salem, NC
	Crystal Gateway Marriott Hotel - Arlington, VA
	Hamilton Standard Electronic Manufacturing Facility - Farmington, CT
	Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL
	United Defense, L.P. Ground Systems Division - San Jose, CA
	Naval Undersea Warfare Center Division Keyport - Keyport, WA
	Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA
	Kaiser Electronics - San Jose, CA
	U.S. Army Combat Systems Test Activity - Aberdeen, MD
	Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM
	Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA
	(Resurvey of Rockwell International Corporation Collins Defense Communications)
	Lockheed Martin Electronics & Missiles - Orlando, FL
	McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO
	(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)
	Dayton Parts, Inc. - Harrisburg, PA
	Wainwright Industries - St. Peters, MO
	Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX
	(Resurvey of General Dynamics Fort Worth Division)
	Lockheed Martin Government Electronic Systems - Moorestown, NJ
	Sacramento Manufacturing and Services Division - Sacramento, CA
	JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN
	Mason & Hanger Corporation - Pantex Plant - Amarillo, TX
	Nascote Industries, Inc. - Nashville, IL
	Weirton Steel Corporation - Weirton, WV
	NASA Kennedy Space Center - Cape Canaveral, FL
	Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL
	SAE International and Performance Review Institute - Warrendale, PA
	Polaroid Corporation - Waltham, MA
	Cincinnati Milacron, Inc. - Cincinnati, OH
	Lawrence Livermore National Laboratory - Livermore, CA
	Sharretts Plating Company, Inc. - Emigsville, PA
	Thermacore, Inc. - Lancaster, PA
	Rock Island Arsenal - Rock Island, IL
	Northrop Grumman Corporation - El Segundo, CA
	(Resurvey of Northrop Corporation Aircraft Division)
	Letterkenny Army Depot - Chambersburg, PA
	Elizabethtown College - Elizabethtown, PA
	Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA
	Strite Industries Limited - Cambridge, Ontario, Canada
	Northrop Grumman Corporation - El Segundo, CA